Claims

[c1] 1. A method for synchronizing frames of imaging data with physiologic data, comprising the following steps:

(a) acquiring frames of imaging data representing a succession of images of a patient"s heart during a study using an imaging system;

(b) automatically time stamping each acquired frame with respective times generated by a first clock;

(c) automatically determining respective offsets of said first clock relative to a reference clock for each time stamp associated with said acquired frames;

(d) storing said acquired frames and said time stamps and said offsets associated with said acquired frames;

(e) acquiring physiologic data from said patient during said study using a hemodynamic monitoring system;

(f) automatically time stamping data in said acquired physiologic data representing one or more predetermined cardiac events with respective times generated by a second clock;

(g) automatically determining respective offsets of said second clock relative to said reference clock for each time stamp associated with said physiologic data; and

(h) storing said acquired physiologic data and said time stamps and said offsets associated with said acquired physiologic data.

[c2] 2. The method as recited in claim 1, further comprising the steps of:

(i) computing which one of said acquired frames was acquired in substantial synchronism with a first predetermined cardiac event based on said time stamps and said offsets; and

(j) associating a first acquired frame identified by step (i) with said first predetermined cardiac event.

[c3] 3. The method as recited in claim 2, further comprising the step of displaying said first acquired frame of imaging data concurrently with physiologic data having a visual indicator indicating a physiologic datum corresponding to said first predetermined cardiac event.

[c4] 4. The method as recited in claim 2, further comprising the step of performing quantitative coronary analysis based at least in part on said first acquired frame.

[c5] 5. The method as recited in claim 2, further comprising the steps of:
(k) computing which one of said acquired frames was acquired in substantial synchronism with a second predetermined cardiac event based on said time stamps and said offsets; and
(l) associating a second acquired frame identified by step (k) with said second predetermined cardiac event.

[c6] 6. The method as recited in claim 5, further comprising the step of performing left ventricular analysis based at least in part on said first and second acquired frames.

[c7] 7. The method as recited in claim 5, wherein said first and second predetermined cardiac events are the diastole and systole of the same cardiac cycle.

[c8] 8. The method as recited in claim 1, further comprising the steps of automatically performing ECG analysis on said acquired physiologic data to identify said acquired physiologic data representing said predetermined cardiac events.

[c9] 9. The method as recited in claim 1, wherein step (g) is performed using a distributed network clock synchronization protocol.

[c10] 10. The method as recited in claim 1, wherein said acquired frames of imaging data and said acquired physiologic data are stored in an asynchronous server.

[c11] 11. The method as recited in claim 1, wherein each of said acquired frames of imaging data is encapsulated in a DICOM object having a header containing respective fields for an associated time stamp and an associated offset.

[c12] 12. The method as recited in claim 1, wherein said imaging data is acquired using X-rays.

[c13] 13. The method as recited in claim 1, further comprising the step of injecting a

contrast agent into the cardiovascular system of said patient before said frames of imaging data are acquired.

[c14] 14. The method as recited in claim 1, wherein said physiologic data comprises electrocardiogram waveform data.

[c15] 15. The method as recited in claim 1, wherein said physiologic data comprises blood pressure measurement data.

[c16] 16. The method as recited in claim 1, wherein one of said predetermined cardiac events is the onset of cardiac contraction.

[c17] 17. The method as recited in claim 1, wherein one of said predetermined cardiac events is peak cardiac contraction.

[c18] 18. A cardiology analysis system comprising an operator interface, a display monitor and a computer programmed to perform the following steps:
compensating for a lack of synchronism between a first clock used to time stamp a plurality of acquired frames of imaging data and a second clock used to time stamp acquired physiologic data representing predetermined cardiac events; and
selecting a first selected frame that was acquired at a time substantially the same as the time when a first predetermined cardiac event occurred based on the results of said compensating step.

[c19] 19. The system as recited in claim 18, wherein said computer is further programmed to control said display monitor to display said selected frame.

[c20] 20. The system as recited in claim 18, wherein said computer is further programmed to perform quantitative coronary analysis based at least in part on said first selected frame.

[c21] 21. The system as recited in claim 18, further comprising the step of selecting a second selected frame that was acquired at a time substantially the same as the time when a second predetermined cardiac event occurred based on the results of said compensating step.

[c22] 22. The system as recited in claim 21, wherein said computer is further programmed to perform left ventricular analysis based at least in part on said first and second selected frames.

[c23] 23. The system as recited in claim 18, wherein each of said acquired frames of imaging data is encapsulated in a DICOM object having a header containing respective fields for an associated time stamp and an associated offset, said offsets being used in said compensating step.

[c24] 24. A system comprising:
an imaging system programmed to time stamp acquired frames of imaging data based on time measured by a first local clock;
a hemodynamic monitoring system programmed to time stamp acquired physiologic data corresponding to predetermined cardiac events based on time measured by a second local clock; and
a first computer programmed to communicate reference clock time to said imaging system and to said hemodynamic monitoring system in accordance with a network time synchronization protocol,
wherein said imaging system and said hemodynamic monitoring system are each further programmed to perform the following steps:
(a) calculating a respective link delay;
(b) calculating a respective local offset; and
(c) associating each of said local offsets with a respective time stamp.

[c25] 25. The system as recited in claim 24, wherein steps (a) through (c) are performed periodically by said imaging system and by said hemodynamic monitoring system.

[c26] 26. The system as recited in claim 24, further comprising a database, said first computer being further programmed to manage said database, and said imaging system and said hemodynamic monitoring system each being further programmed to upload files to said database, each file containing acquired imaging or physiologic data, a respective time stamp representing when said data was acquired, and a respective local offset representing the magnitude of time by which a respective one of said first and second local clocks is out of

synchronization with reference to said reference clock.

[c27] 27. The system as recited in claim 26, wherein each of said files is in the format of a respective DICOM object, each DICOM object containing a header comprising a respective time stamp and a respective local offset.

[c28] 28. The system as recited in claim 26, further comprising a second computer programmed to perform the following steps:
receiving files from said database via said first computer;
selecting a frame of imaging data acquired by said imaging system at a time substantially synchronized with a predetermined cardiac event recorded in said physiologic data acquired by said hemodynamic monitoring system, said frame selection being based at least in part on computation of differences between local offsets in files containing imaging data and local offsets in files containing physiologic data; and
performing quantitative analysis based at least in part on said selected frame of imaging data.

[c29] 29. The system as recited in claim 26, further comprising a second computer programmed to perform the following steps:
receiving files from said database via said first computer;;
matching frames of imaging data acquired by said imaging system with physiologic data corresponding to predetermined cardiac events acquired by said hemodynamic monitoring system, said frame matching being based at least in part on computation of differences between local offsets in files containing imaging data and local offsets in files containing physiologic data; and
performing quantitative analysis based at least in part on one or more of said selected frames of imaging data.

[c30] 30. A system comprising:
an imaging system programmed to time stamp acquired frames of imaging data based on time measured by a first local clock;
a hemodynamic monitoring system programmed to time stamp acquired physiologic data corresponding to predetermined cardiac events based on time measured by a second local clock; and

a first computer programmed to communicate reference clock time to said imaging system and to said hemodynamic monitoring system in accordance with a network time synchronization protocol,
wherein said imaging system and said hemodynamic monitoring system are each further programmed to perform the following steps:
(a) calculating a respective link delay;
(b) calculating a respective local offset; and
(c) adjusting a respective one of said first and second local clocks to match said reference clock,
said time stamps of said imaging system and said hemodynamic monitoring system being respectively derived from said adjusted first and second local clocks.

[c31] 31. The system as recited in claim 30, wherein steps (a) through (c) are performed periodically by said imaging system and by said hemodynamic monitoring system.

[c32] 32. The system as recited in claim 30, further comprising a database, said first computer being further programmed to manage said database, and said imaging system and said hemodynamic monitoring system each being further programmed to upload files to said database, each file containing acquired imaging or physiologic data, a respective time stamp representing when said data was acquired.

[c33] 33. The system as recited in claim 32, wherein each of said files is in the format of a respective DICOM object, each DICOM object containing a header comprising a respective time stamp.

[c34] 34. The system as recited in claim 32, further comprising a second computer programmed to perform the following steps:
receiving files from said database via said first computer;;
selecting a frame of imaging data acquired by said imaging system at a time substantially synchronized with a predetermined cardiac event recorded in said physiologic data acquired by said hemodynamic monitoring system, said frame selection being based on comparison of time stamps in files containing imaging

data with time stamps in files containing physiologic data, said selected frame having a time stamp that differs from a time stamp associated with a physiologic datum corresponding to said predetermined cardiac event by a minimum amount; and

performing quantitative analysis based at least in part on said selected frame of imaging data.

[c35] 35. The system as recited in claim 32, further comprising a second computer programmed to perform the following steps:

receiving files from said database via said first computer;;

matching frames of imaging data acquired by said imaging system with physiologic data corresponding to predetermined cardiac events acquired by said hemodynamic monitoring system, said frame matching being based at least in part on computation of differences between time stamps in files containing imaging data and time stamps in files containing physiologic data, each matched frame having a time stamp that differs from a respective time stamp associated with a respective physiologic datum corresponding to a respective one of said predetermined cardiac events by a minimum amount; and

performing quantitative analysis based at least in part on one or more of said selected frames of imaging data.

[c36] 36. A method for synchronizing a frame of imaging data with a physiologic datum, comprising the following steps:

(a) automatically determining a first offset of a first local clock relative to a reference clock, said first local clock dictating the time of day in an imaging system;

(b) automatically adjusting said first local clock by an amount that is a function of said first offset to synchronize said first local clock with said reference clock;

(c) automatically determining a second offset of a second local clock relative to said reference clock, said second local clock dictating the time of day in an hemodynamic monitoring system;

(d) automatically adjusting said second local clock by an amount that is a function of said second offset to synchronize said second local clock with said reference clock;

(e) acquiring a frame of imaging data representing an image of a patient"s heart during a study using said imaging system;
(f) automatically time stamping said acquired frame with a time generated by said adjusted first local clock;
(g) storing said acquired frame and said time stamp associated with said acquired frame as an imaging file;
(h) acquiring physiologic data from said patient during said study using said hemodynamic monitoring system;
(i) automatically time stamping a datum in said acquired physiologic data representing a predetermined cardiac event with a time generated by said adjusted second local clock; and
(j) storing said acquired physiologic data and said time stamp associated with said acquired physiologic data as a physiology file.

[c37] 37. The method as recited in claim 36, wherein steps (a) through (j) are performed repeatedly over the course of a study to acquire a multiplicity of frames of imaging data and physiologic data, further comprising the steps of:
selecting a frame of imaging data acquired by said imaging system at a time substantially synchronized with a predetermined cardiac event recorded in said physiologic data acquired by said hemodynamic monitoring system, said frame selection being based on comparison of time stamps in imaging files with time stamps in physiology files, said selected frame having a time stamp that differs from a time stamp associated with a physiologic datum corresponding to said predetermined cardiac event by a minimum amount; and
performing quantitative analysis based at least in part on said selected frame of imaging data.